Expansion dynamics after laser-induced cavitation in liquid tin microdroplets

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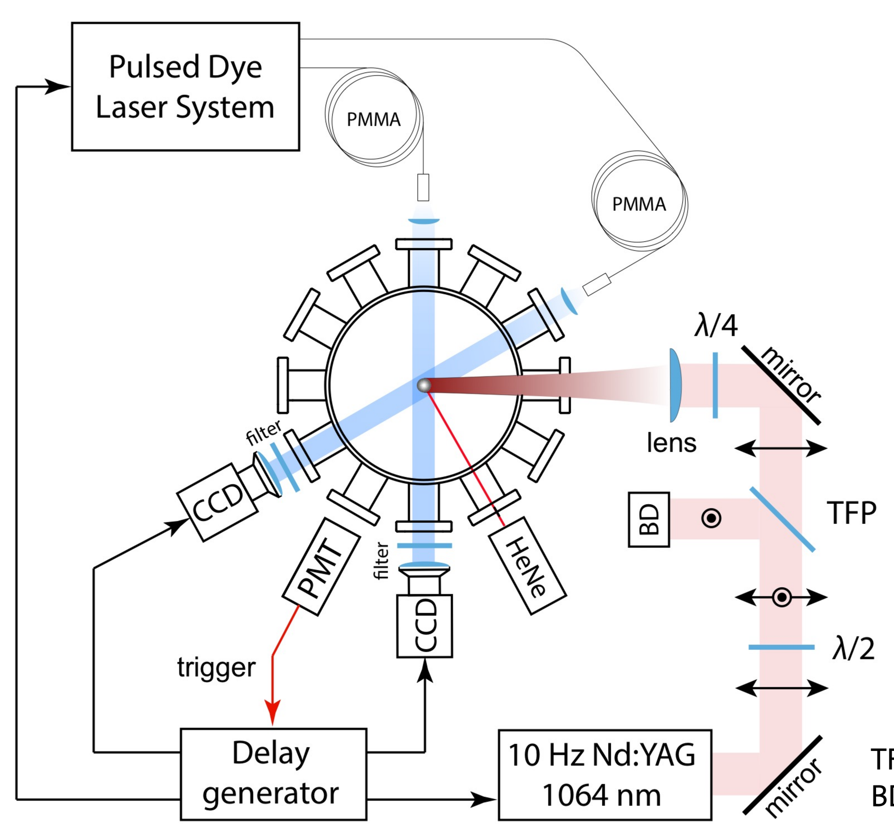
We present a detailed analysis of the expansion dynamics of liquid tin microdroplets after picosecond-laser-induced cavitation, combining high-quality stroboscopic shadowgraphy with an intuitive fluid dynamic model. Excellent agreement with our model is obtained regarding the hydrodynamic scalability of the data with expansion velocity as well as for two different droplet sizes.

10Hz tin plasma-based EUV light source



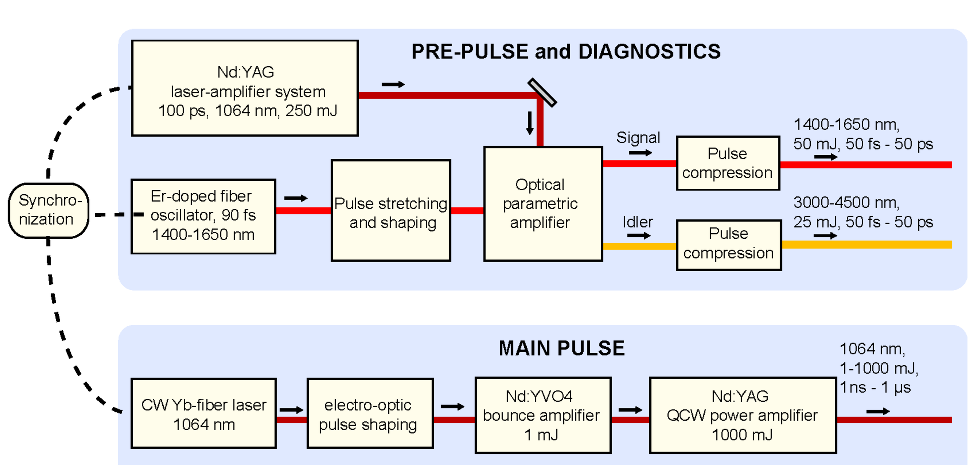
Droplet generator based on piezo-driven nozzle operated with Sn.

Two (three)-side **shadowgraph imaging** based on:

- 560 nm dye laser (5 ns pulse)
- Long-distance microscopes with NIR CCD cameras

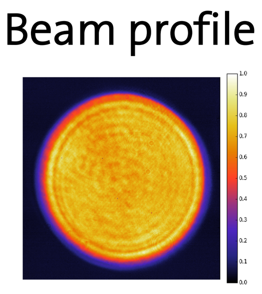
TFP – thin film polarizer;
BD – beam dump.

Advanced Nd:YAG laser system



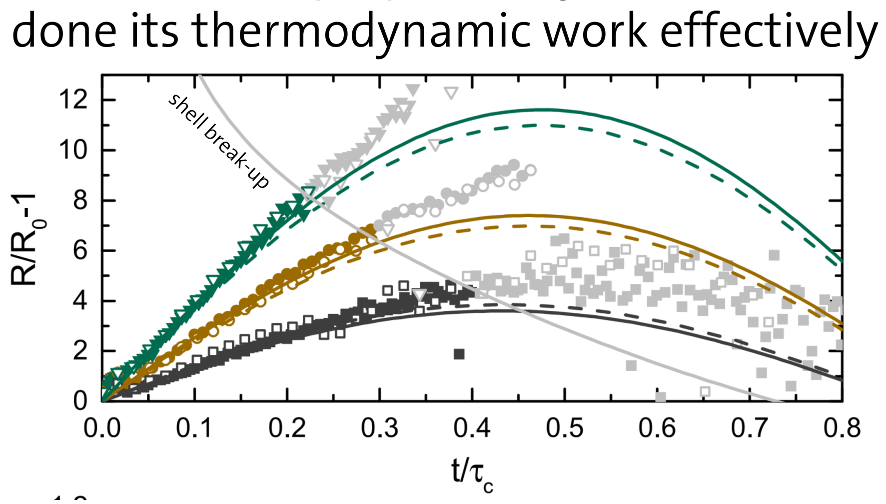
- Pulse duration 15-110 ps
- Up to 40 mJ/pulse @ 100 Hz

Beam profile



Radial expansion

To describe the time evolution of the thin tin sheet, we assume that the acceleration of the liquid is very fast, on the nanosecond time scale, and ends well before significant and visible expansion occurs. Thus, a spherically symmetric shell is expanding at an initial velocity radial velocity in a vacuum propelled by its inertia, with the cavitation bubble having done its thermodynamic work effectively at time zero.



solid lines:

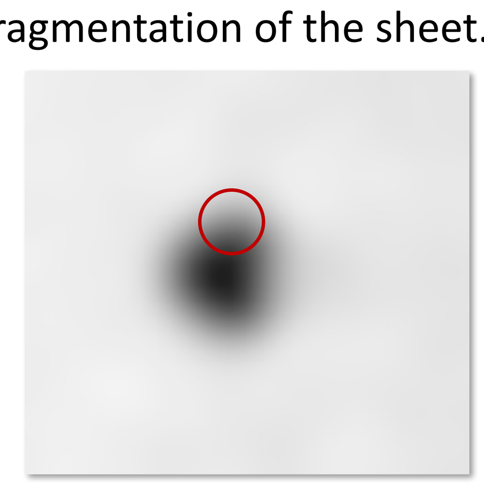
$$\frac{R(t)}{R_0} = \cos\frac{\pi t}{\tau_c} + \sqrt{We}\,\sin\frac{\pi t}{\tau_c}$$

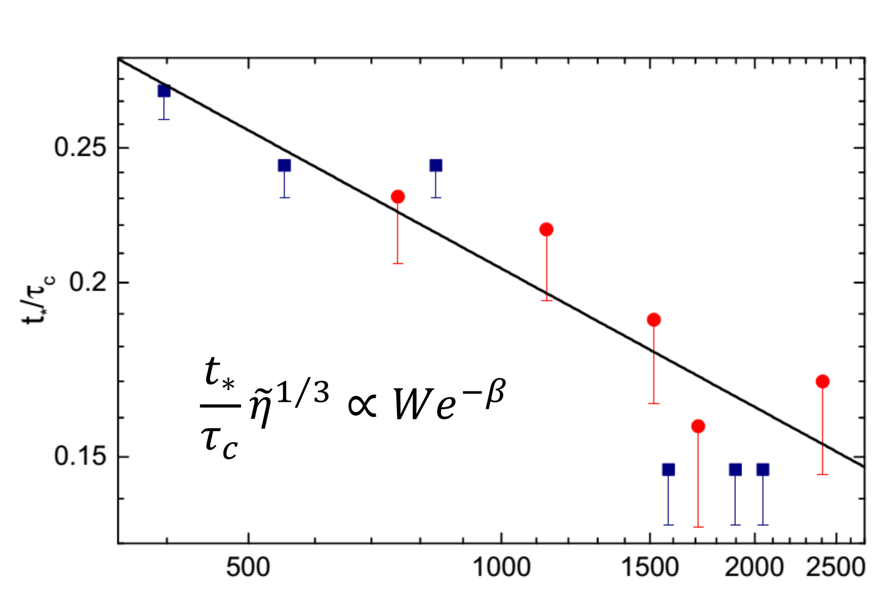
$$\mathrm{We} = \rho R_0 \dot{R}^2_{t=0}/\sigma$$

$$\tau_c = \sqrt{\rho R_0^3/6\sigma}$$

Shell break-up

The expanding shell is a subject to Rayleigh-Taylor instabilities. This will lead to hole formation after which rapid hole opening and merging will lead to full fragmentation of the sheet.

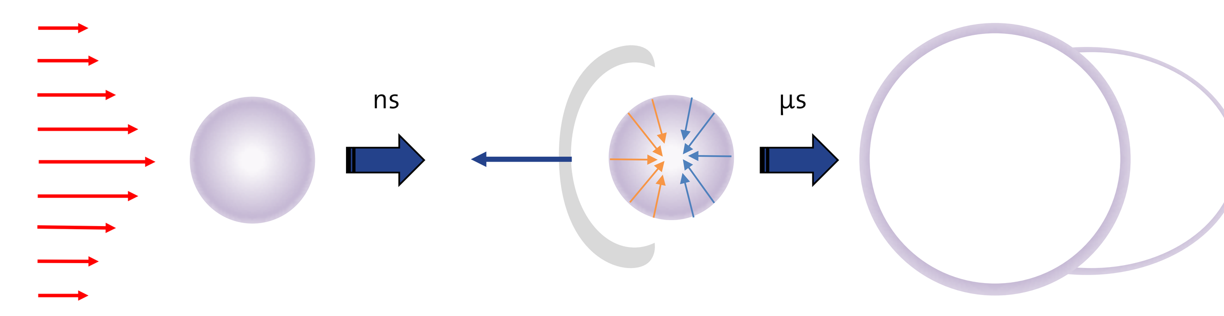




We - Weber number
τ_c - capillary time
t_* - time when holes appears
$\tilde{\eta}$ - the initial amplitude normalized by droplet radius

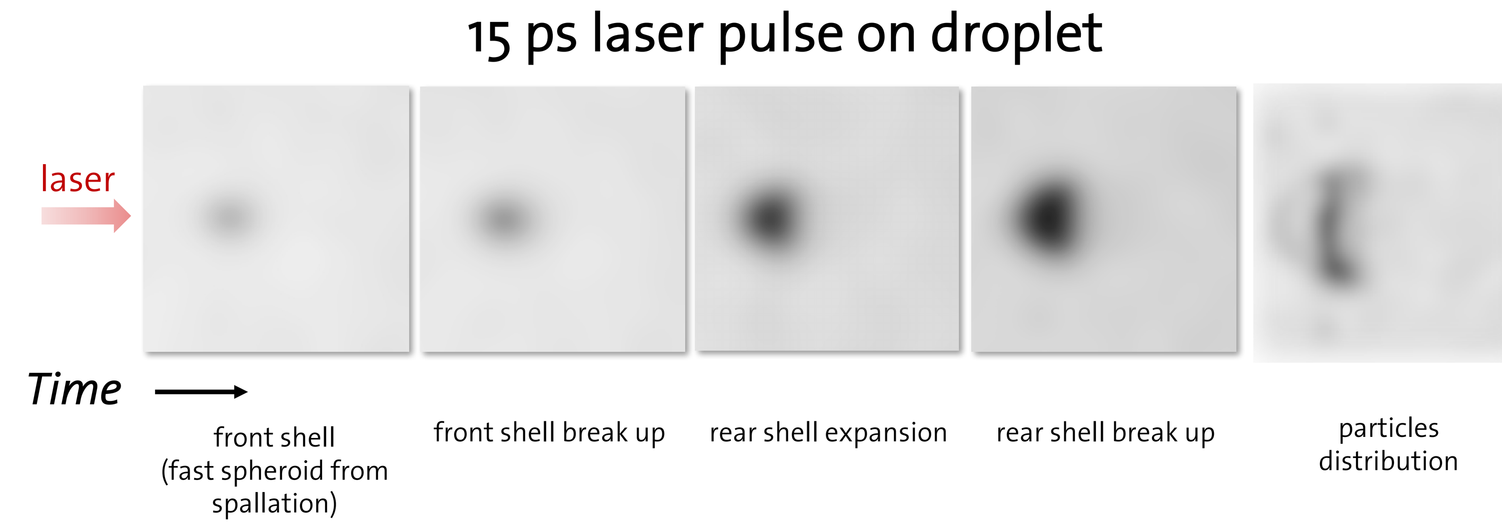
Kurilovich et al. *in preparation*

Picosecond laser pulse impact on tin microdroplets

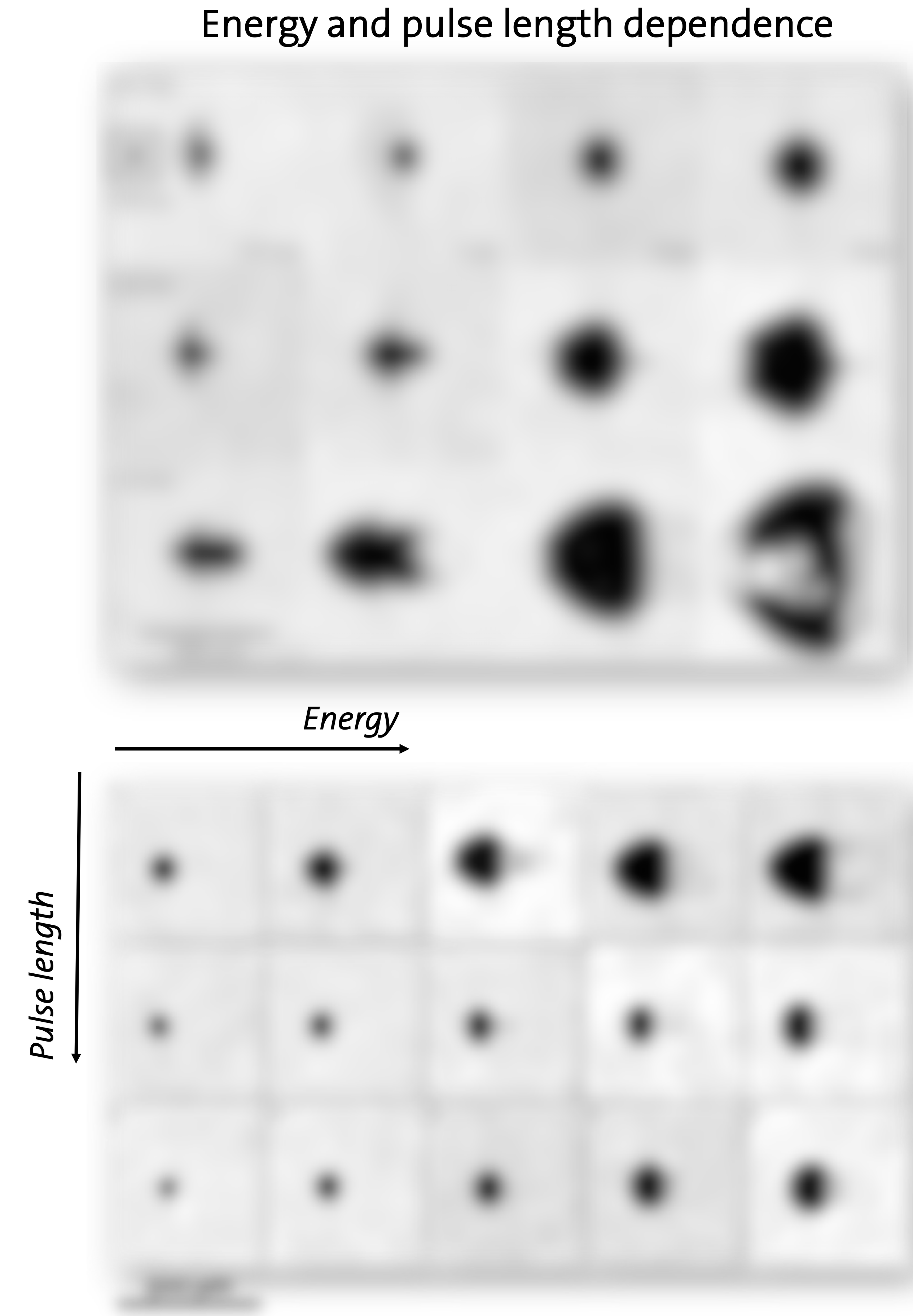


A. Y. Vinokhodov et al, Quant. Electr. **46**, 23 (2016)
M. M. Basko et al, Laser Phys. Lett. **14**, 036001 (2017)
M. Krivokorytov et al, Phys. Rev. E **95**, 031101 (2017)

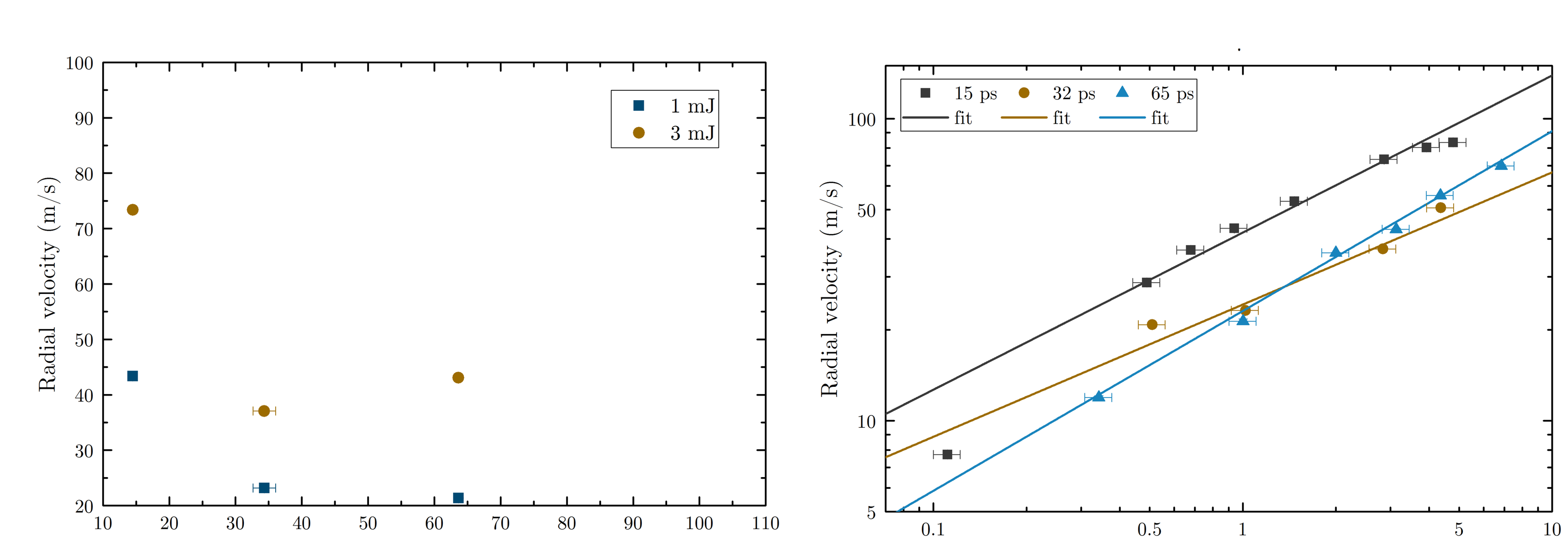
15 ps laser pulse on droplet



Energy and pulse length dependence



Radial velocity as a function of laser pulse length and energy



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